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Fire eater's lung: Retrospective analysis of 123 cases reported to a national poison center

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Abstract: Background: Fire eater's lung (FEL) is a distinct form of acute chemical toxic pneumonitis, which is caused by aspiration of flammable petrochemical derivatives used by street performers for 'fire eating'. The optimal management of this condition has not yet been determined. **Objective:** The aim of this study was to investigate patient characteristics, clinical features, treatment, and outcome of FEL. **Methods:** A single-center retrospective review of consecutive cases of FEL in children and adults reported to a national poison center (the Swiss Toxicological Information Center) between 1995 and 2012. **Results:** 123 cases (83.7% males, mean age 21.9 years) were included. The most frequently reported symptom was cough (50.4%), followed by chest pain (45.5%), and fever (35.8%). Dyspnea was reported by 23.6%. Cough ($p = 0.002$) and chest pain ($p = 0.02$) were significantly more prevalent in subjects reporting to have aspirated the fuel compared to those who have swallowed it or who did not perceive poison exposure. A pulmonary infiltrate was detected in 83% of the cases in whom chest X-ray was performed. Overall, 22% were treated with an antibiotic agent for a mean duration of 10.4 days. Corticosteroids were administered in 4.9%. All showed complete recovery irrespective of the therapeutic management. **Conclusion:** The combination of intense pleuritic chest pain, cough, dyspnea, and fever, or any of these symptoms after 'fire eating' or erroneous swallowing of a petroleum distillate should alert the clinician to the diagnosis of FEL. Early antibiotic treatment of severe cases seems justified, considering that clinical, laboratory, and radiologic findings of FEL are overlapping with bacterial superinfection.

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Fire Eater's Lung: Retrospective Analysis of 123 Cases Reported to a National Poison Center

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Key Words

Acute lung injury · Aspiration · Chemical pneumonitis ·
Fire eating · Petroleum

Abstract

Background: Fire eater's lung (FEL) is a distinct form of acute chemical toxic pneumonitis, which is caused by aspiration of flammable petrochemical derivatives used by street performers for 'fire eating'. The optimal management of this condition has not yet been determined. **Objective:** The aim of this study was to investigate patient characteristics, clinical features, treatment, and outcome of FEL. **Methods:** A single-center retrospective review of consecutive cases of FEL in children and adults reported to a national poison center (the Swiss Toxicological Information Center) between 1995 and 2012. **Results:** 123 cases (83.7% males, mean age 21.9 years) were included. The most frequently reported symptom was cough (50.4%), followed by chest pain (45.5%), and fever (35.8%). Dyspnea was reported by 23.6%. Cough ($p = 0.002$) and chest pain ($p = 0.02$) were significantly more prevalent in subjects reporting to have aspirated the fuel compared to those who have swallowed it or who did not perceive poison exposure. A pulmonary infiltrate was detected in 83% of the cases in whom chest X-ray was performed.

Overall, 22% were treated with an antibiotic agent for a mean duration of 10.4 days. Corticosteroids were administered in 4.9%. All showed complete recovery irrespective of the therapeutic management. **Conclusion:** The combination of intense pleuritic chest pain, cough, dyspnea, and fever, or any of these symptoms after 'fire eating' or erroneous swallowing of a petroleum distillate should alert the clinician to the diagnosis of FEL. Early antibiotic treatment of severe cases seems justified, considering that clinical, laboratory, and radiologic findings of FEL are overlapping with bacterial superinfection.

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Introduction

Fire eater's lung (FEL) is a distinct form of acute chemical toxic pneumonitis, which is caused by accidental aspiration of flammable petrochemical derivatives, like petroleum or its distillate used by street performers for 'fire eating'. Due to the low viscosity of these hydrocarbons, there is a rapid diffusion throughout the bronchial mucosa sometimes leading to severe pulmonary and systemic inflammation after aspiration [1]. To date, the largest case series evaluating patients with FEL includes 17 cases

only [2]. Thus, the optimal management of FEL has not yet been determined, and some controversies exist, particularly regarding the initiation of antibiotic therapy and administration of glucocorticoids. In the present study, we investigated patient characteristics, circumstances, clinical patterns and treatment of 123 consecutive FEL cases reported to a single national poison center (the Swiss Toxicological Information Center, STIC) between 1995 and 2012.

Methods

Swiss Toxicological Information Center

The STIC provides on 7 days/week a 24-hour, nationwide, free medical advice to health care professionals and the general public for the management of cases of human poisoning by any substance. The requests for information are obtained by telephone. In 2011, the STIC handled 35,576 enquiries. Demographic and detailed clinical information on exposure cases, circumstances of the poisoning, symptoms/signs and advice provided are recorded in a systematic and standardized manner by clinical toxicologists. These data are anonymized and prospectively entered into an in-house structured electronic database. For reports by health care professionals, the STIC collects additional specific clinical data, including therapeutic interventions and the observed clinical course using standardized report forms, which are sent to the treating physicians during the days following the initial contact. Hospital physicians are also asked to provide a discharge letter and any laboratory results, as well as the results of other examinations. This follow-up information is then matched with the data taken during the initial call, anonymized, and entered into the database to complement the case files. Each case is subsequently reviewed by an experienced clinical toxicologist to ensure completeness and correctness of the data recorded.

Subjects

Between January 1, 1995, and June 30, 2012, all consecutive cases of FEL involving adults or children (defined as 16 years or younger) reported to the STIC were included in the study. Demographic data, circumstances of poisoning, offending agents and observed symptoms/signs of all cases were collected. The severity of symptoms of individual patients was classified as 'minor' if only mild and transient symptoms/signs were present, as 'moderate' if at least one pronounced or prolonged symptom/sign was recorded, or as 'severe' if at least one severe or life-threatening symptom was observed. This classification is in accordance with the Poisoning Severity Score (PSS) developed by the European Association of Poison Centers and Clinical Toxicologists, the WHO International Program on Chemical Safety, and the European Commission [3].

Outcome and Follow-Up

The objective of this study was to describe the symptoms and clinical presentation of FEL, and, secondly, to investigate the outcome. For the latter purpose, we collected and analyzed outcome data in those patients in whom physician-based follow-up information, (e.g. patient record files and case-specific queries) was available (24 of the 123 subjects (19.5%)).

Statistical Analysis

Data are reported as means \pm SD or percentages. Differences in clinical presentation between different circumstances of poisoning (aspiration vs. swallowing) were estimated using one-way ANOVA for continuous variables and χ^2 test or Fisher's exact test for categorical variables. *p* values of all outcomes were two-sided, and values of *p* < 0.05 were considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corporation, Armonk, N.Y., USA).

The study was performed according to the local legality concerning retrospective, previously anonymized data in concordance with the Ethics Committee of the Canton Zurich, Switzerland.

Results

Subject Characteristics and Details of Poisoning

During the 17.5 years, a total of 123 FEL cases (103 males, 83.7%) were reported to the STIC after accidental aspiration or ingestion of petroleum or another inflammable petrochemical fluid. Sixty-eight (54.9%) enquiries originated from physicians, and 55 (45.1%) from the general public. Their mean age was 21.9 (± 11.1) years. Of the 123 cases reported, 99 (80.5%) were adults and 24 children. The mean time between aspiration/ingestion of the ignition fluid and reporting to the STIC was 23.6 h, with a minimum interval of 5 min to a maximum of 20 days. The most frequently reported offending agent, referred to later in the text as 'fuel', was petroleum or an unspecified petroleum distillate (*n* = 115, 95%). Other petrochemical fluids were alkanes other than petroleum (*n* = 3, 2.5%), ethanol (*n* = 2, 1.7%) or kerosene (*n* = 1, 0.8%). Most of the cases occurred during 'fire eating/breathing' (*n* = 117, 95.9%), whereas 5 were reported after swallowing of fuel, which was erroneously mistaken for a beverage (intentional swallowing). No case of suicidal ingestion was reported. The mechanism of poisoning was a perceived aspiration in 49 (39.8%) and swallowing in 84 cases (68.3%), respectively, including 28 subjects (22.8%) with both aspiration and swallowing. In 18 symptomatic cases (14.6%), the mechanism of poisoning could not be indicated. Demographic data are summarized in table 1.

Symptoms and Signs

The most frequently reported symptom was cough in 62 cases (50.4%), followed by chest pain (*n* = 56, 45.5%), and fever (*n* = 44, 35.8%). The mean body temperature in febrile subjects was 38.3°C ($\pm 0.7^\circ\text{C}$, maximum 40.0°C, minimum 37.5°C). Dyspnea was reported by 29 subjects (23.6%), whereas hypoxemia, defined as oxygen saturation on ambient air <92%, was present in 10 cases (8.1%)

Fig. 1. Symptoms of FEL in 123 subjects with suspected or confirmed FEL reported to the STIC between 1995 and 2012; in 24 patients with confirmed FEL, physician-based follow-up data were available.

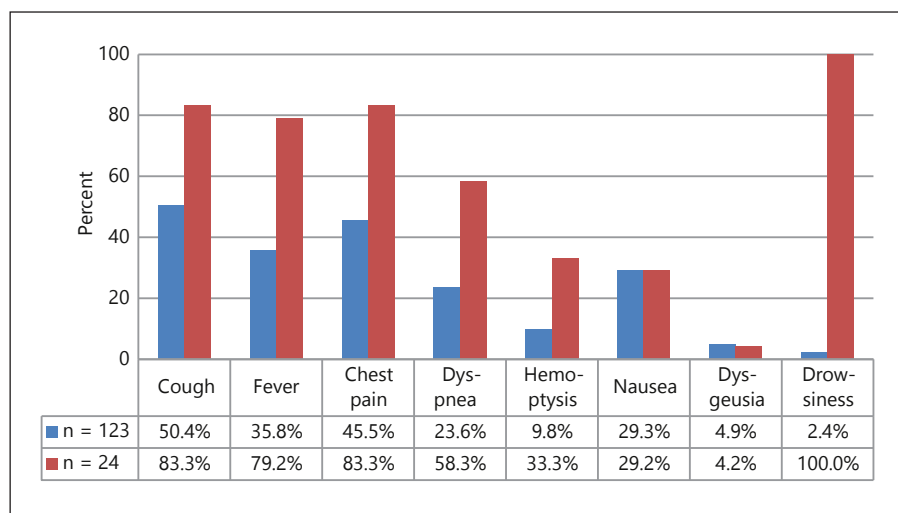


Table 1. Demographic characteristics of the 123 consecutive FEL cases reported to the STIC between 1995 and 2012

Characteristics	All cases reported (n = 123)
Male gender, n (%)	103 (83.7)
Age, years	21.9 (11.1)
Adults >16 years, n (%)	99 (80.5)
Time from exposure to reporting, h	23.6 (51.1)
Offending agent: petroleum or unspecified petroleum distillate, n (%)	115 (95.0)
Circumstances	
‘Fire breathing’, n (%)	117 (95.9)
Intentional swallowing ^a , n (%)	5 (4.1)
Mechanism	
Aspiration, n (%)	49 (39.8) ^b
Swallowing, n (%)	84 (68.3) ^b
Both aspiration and swallowing, n (%)	28 (22.8)
Neither aspiration nor swallowing (unperceived exposure), n (%)	18 (14.6)

Values are means (SD) where applicable. ^a Fuel was erroneously mistaken for a beverage. ^b Double listing due to 28 patients with a combined mechanism (both aspiration and swallowing).

only. Twelve subjects suffered from minor hemoptysis (9.8%). In 36 fire eaters (29.3%), gastrointestinal symptoms like nausea or vomiting were reported. Six subjects (4.9%) mentioned a prolonged distortion of the sense of taste. Three persons (2.4%) reported drowsiness after the fire-eating accident. In none of the cases there was evidence of hemodynamic instability. The mean systolic/di-

astolic blood pressure in 22 patients, in whom data were available, was 124/70 mm Hg and the minimal blood pressure was 110/54 mm Hg. The mean heart rate was 99/min (minimum 70/min, maximum 138/min). Severity classification according to PSS [3] was performed in 36 cases, in whom sufficient information was available. Of these, 19.4% showed only mild symptoms, whereas 69.4% had moderate and 11.1% severe symptoms.

In total, conventional chest radiography (CXR) was performed in 48 subjects (39.0%). Of these, 39 (83.0%) had a pathological finding revealing a pulmonary infiltrate. The most commonly reported localization of the CXR finding was the right lower lung field (65.5%). In 32.0%, infiltrates occurred bilaterally in both lower fields. Results of blood examinations were available for 30 subjects (24.4%). Elevated inflammatory markers (elevated C-reactive protein >10 mg and/or leukocyte count >10.0 × 10⁶/l) were found in 29 (96.7%). The mean C-reactive protein level was 180.7 mg/l (±132.5, maximum 495, minimum 12 mg/l), and the mean leukocyte count was 17.5 × 10⁶/l (± 4.7, maximum 28.0, minimum 10.6 × 10⁶/l). Bronchoscopy was performed in 1 subject only, and it did not add to diagnosis. Symptoms and signs of all subjects with suspected or confirmed FEL are summarized in figure 1 and table 2. Typical examples of CXR and computed tomography imaging are shown in figures 2 and 3, respectively.

Factors Influencing Symptoms and Signs

The route of poisoning (aspiration vs. ingestion vs. unperceived mechanism vs. combined swallowing and ingestion) had no significant influence on the severity of the



Fig. 2. Conventional CXR of a 38-year-old male presenting with acute pneumonitis after fire eating revealing rounded, sharply bordered infiltrations of both lower lobes, which suggests pneumatoceles, stressing the diagnosis of FEL in the appropriate clinical context.

Table 2. Clinical findings of the 123 consecutive FEL cases reported to the STIC between 1995 and 2012

Clinical findings	All cases reported (n = 123)
Mean blood pressure (systolic/diastolic), mm Hg (SD)	124 (12.4)/70 (10.5)
Mean heart rate, beats/min (SD)	99 (15.8)
CXR performed, n (%)	48 (39.0)
Pathologic finding (consolidation), n (%)	39 (83.0)
Right lower lobe consolidation, n (%)	19 (65.5)
Bilateral lower lobe consolidation, n (%)	9 (31.0)
Laboratory examination performed, n (%)	28 (22.8)
Elevated inflammation parameters (CRP >10 mg/l and/or leukocyte count >10.0 × 10 ⁶ /l), n (%)	29 (96.7)
Mean CRP, mg/l (SD)	180.7 (132.5)
Mean leukocyte count, ×10 ⁶ /l (SD)	14.5 (4.7)
CRP = C-reactive protein.	

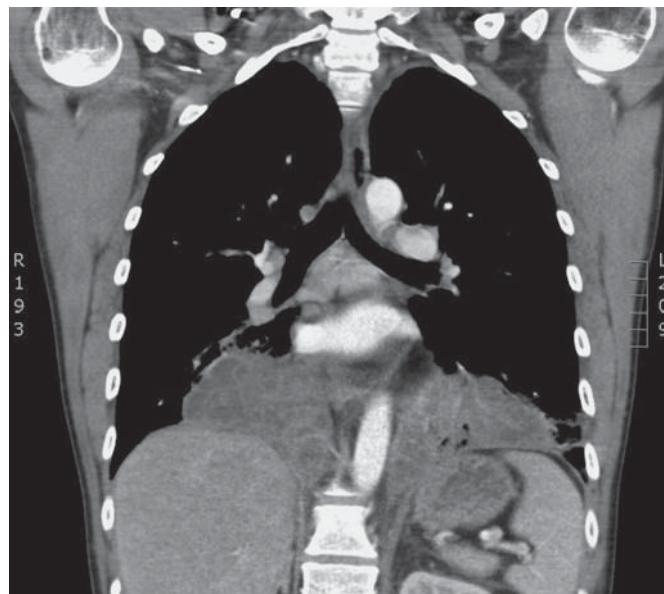


Fig. 3. Thoracic computed tomography (mediastinal window, coronal view) of the same patient confirming the presence of pneumatoceles and extensive pulmonary consolidation of decreased attenuation in both lower lungs. The appropriate clinical context (history of fire eating, severe chest pain, elevated inflammatory markers) suggests the diagnosis of FEL.

clinical picture classified according to PSS ($p = 0.09$; table 3). Cough (68.8%, $p = 0.002$) and chest pain (60.4%, $p = 0.02$) were significantly more prevalent in subjects deemed to have aspirated the fuel compared to those who had swallowed it (42.0 and 40.7%, respectively), or who did not perceive poison exposure (61.1 and 55.5%, respectively). In contrast, in case of unperceived poison exposure (neither swallowing nor aspiration), the proportion of febrile (50.0%) and breathless (50.0%) subjects was significantly higher compared to those who swallowed (28.4 and 17.3%, respectively) or aspirated (43.8 and 25.0%, respectively) the fuel ($p = 0.02$ and $p = 0.01$, respectively). Other clinical symptoms and signs were equally distributed between the different routes of fuel exposure. Notably, the route of poisoning had no impact on the prevalence of gastrointestinal symptoms. In cases of combined aspiration and swallowing, no symptom was more prevalent than another one.

Management

In total, antibiotic treatment was reported to be administered in 27 subjects (22.0%). Of these, 70.8% were treated with amoxicillin/clavulanic acid and 29.2% with a new generation quinolone antibiotic (moxifloxacin or

Table 3. Signs and symptoms of FEL among different subgroups according to the most common poisoning mechanisms

	Aspiration (n = 49)	Swallowing (n = 84)	Unperceived poison exposure (n = 18)	p value
Mean PSS (SD)	2.1 (0.3)	1.9 (0.5)	2.0 (0.0)	NS
Cough	33 (68.8%)	34 (42.0%)	11 (61.1%)	0.002
Fever	21 (43.8%)	12 (28.4%)	9 (50.0%)	0.02
Chest pain	29 (60.4%)	33 (40.7%)	10 (55.6%)	0.02
Dyspnea	12 (25.0%)	14 (17.3%)	9 (50.0%)	0.01
Hemoptysis	7 (14.6%)	6 (7.4%)	2 (11.1%)	NS
Nausea	10 (20.8%)	29 (35.8%)	4 (22.2%)	NS
Drowsiness	2 (4.2%)	2 (2.5%)	0	NS
Distortion of taste	2 (4.2%)	1 (1.2%)	3 (16.7%)	NS

One-way ANOVA was performed for continuous variables (PSS), and the χ^2 test for categorical variables; NS = Nonsignificant. PSS severity was graded as (0) none, (1) minor, (2) moderate, (3) severe, and (4) fatal poisoning.

ofloxacin). Mean duration of antibiotic treatment was 10.4 days (± 4.6 , maximum 21, minimum 5 days). In 6 subjects (4.9%), corticosteroid treatment was initiated. In 5 of these, corticosteroid therapy was combined with antibiotics.

Management and Outcome of Cases with Available Follow-Up

Of the 24 patients in whom information on follow-up was available, 18 (75%) were hospitalized due to FEL for a mean duration of 5.1 days (± 4.1 , minimum 1, maximum 19 days). Antibiotic treatment was given in 17 of these 24 patients during a mean duration of 10.9 days (± 4.7 , maximum 21, minimum 5 days). Fourteen subjects were treated with amoxicillin/clavulanic acid, and 3 with moxifloxacin. Six patients received a corticosteroid treatment, but in 5 of these, it was combined with antibiotics. Symptoms and signs of FEL and the PSS were equally distributed between the different treatment strategies. Also, length of hospital stay did not differ significantly between both antibiotic regimes ($p = 0.36$). All patients showed full recovery without any residual symptoms irrespective of the treatment performed. In 3 patients treated with moxifloxacin (mean duration 16.3 days, range 7–21 days), serial follow-up examinations including CXR, laboratory and lung function measurements were available. These patients showed a complete radiological and (lung) functional recovery.

Discussion

Aspiration of flammable petrochemical derivatives (e.g. petroleum) typically leads to severe inflammatory responses of lung tissue, also called hydrocarbon pneumonitis or FEL. Commonly, this incident is reported in association with fire eating performed by professional or amateur street artists. Actually, FEL is provoked by the act of creating a fireball by breathing a fine mist of fuel over an open flame, which is called 'fire breathing' (dragon's breath) [4–6]. The most likely mechanism for the development of FEL is that petroleum or other highly inflammable agents remaining in the mouth after flame blowing are aspirated with the subsequent deep inspiration [2]. Fire-breathing street artists commonly use petroleum or a volatile petroleum derivative, also called kerdan, which is produced by the distillation process of petroleum between 150 and 240°C [7]. Some street artists prepare individual mixtures composed of volatile substances other than kerdan, or they use other forms of petroleum distillates. As the physicochemical properties of hydrocarbons are different, individual mixtures may alter the clinical presentation, course and outcome of hydrocarbon pneumonitis giving the FEL a slightly variable clinical appearance [2]. Pulmonary injuries from hydrocarbons are due to their low viscosity, low surface tension, and high volatility. These characteristics reduce the effectiveness of the individual's cough and choke reflexes and, moreover, enable diffuse spreading of the fuel in the airway mucosa with a very high absorption rate, which leads to damage of bronchial mucosa and lung tissue [1, 2].

The first description of FEL was published in 1971 by Gerbeaux et al. [8]. Up to now, there are only a few case reports [9–13] and one case series of 17 patients with FEL published [2]. In concordance with these publications, FEL predominantly occurs in young adults with a clear male predominance, and, generally, petroleum or its distillate is the offending agent. We could show that the mechanism of poisoning seems to have an impact on the clinical presentation, as pulmonary symptoms and fever were more prevalent after aspiration compared to swallowing. However, PSS was not influenced by the route of poisoning. Compared to the case series published by Gentina et al. [2], the prevalence of any symptom is quite low in our study. In their study, cough, dyspnea, and chest pain were present in 70.5, 97.0, and 100% of cases compared to 50.4, 23.6, and 45.5% in our study, respectively. Moreover, fever was reported in 97% of the cases in the study by Gentina et al. [2] compared to 35.8% in our study. A possible explanation for these differences might

be underreporting associated with the tele-consultation-based data acquisition in our study on the one hand and a selection bias in the aforementioned study on the other hand [2]. Notably, in the study by Gentina et al. [2], all patients investigated were retrieved from a department of respiratory medicine of a university hospital, making a bias in case selection likely, since mild-to-moderate cases of FEL would probably not be referred to highly specialized clinics. However, in our cohort, the proportion of mild and moderate case severity was 19.4 and 69.4%, respectively. Hence, our data may describe more accurately and comprehensively the prevalence of symptoms associated with FEL. Nevertheless, the combination of intense pleuritic chest pain, cough, dyspnea, and fever, or any of these symptoms after 'fire breathing' or erroneous swallowing of petroleum should alert the clinician to the diagnosis of FEL [13, 14]. According to the literature review performed by Lampert et al. [10], these symptoms commence immediately after petroleum aspiration. Interestingly, the mean time interval from the accident to reporting to the STIC was 23.6 h in our study.

In concordance with other publications, the clinical findings of FEL resemble bacterial pneumonia, with pulmonary infiltrates, mainly in the lower field (83.0% in our study compared to 100% in other studies), and raised inflammation parameters (96.7% in our study compared to 68.8%) [1, 2, 10, 13, 14]. The radiological changes typically occur within 12 h after petroleum aspiration (fig. 2) [2]. In chest computed tomography, these changes would rather appear as extensive pulmonary consolidations of decreased attenuation and pneumatoceles (fig. 3), albeit these findings are not specific for FEL, leaving therefore a broad range of differential diagnoses, including acute bacterial pneumonia [13, 15, 16].

Bronchoscopy was reported only in 1 of the 123 patients in the current study. According to others, we feel that routine bronchoscopy is not helpful in the acute management of FEL, as the initial lung damage is due to toxic exposure rather than infectious origin [10]. Referring to this, Gentina et al. [2] described sterile bronchoalveolar lavage in 3 of 3 reported cases, in whom an immediate bronchoscopy was performed. However, a short- to mid-term complication of FEL is bacterial superinfection, with potentially worse prognosis, as the risk of bacterial superinfection is considered to be increased after aspiration of petroleum [17, 18]. Theoretically, bronchoalveolar lavage is indicated in case of suspected superinfection before initiation of antibiotic treatment.

The aforementioned clinical similarity between FEL as acute toxic pneumonitis and its complication due to bac-

terial superinfection is the main challenge in the management of this condition. Additionally, the distinction between FEL and acute bacterial pneumonia is sometimes demanding, particularly when the relationship between clinical presentation and the aspiration accident is not recognized. The decision to initiate antibiotics in terms of a prophylactic use immediately after clinical presentation of FEL is debatable, as the evidence concerning indication, timing, and choice of an antibiotic prophylaxis is lacking. In the present study, 22% of all patients were treated with an antibiotic agent for a mean duration of 10.4 days, which is a lower than in other reports (75–87%), again reflecting a potential selection bias [4]. Of the 24 patients in whom follow-up data were available, all showed a benign clinical course with complete recovery irrespective of the therapeutic management. The decision to initiate an antibiotic treatment was not influenced by any symptom or clinical severity according to PSS. However, according to our experience and that of others, early antibiotic treatment should be considered in severe cases of FEL [10, 13, 17–19]. Corticosteroids should probably be avoided as they appear to be ineffective or even harmful [20]. A fatal outcome of FEL is exceptional, although the lethal dose of ingested hydrocarbon was found to be 40 ml/kg body weight in animal experiments [21].

Limitations

This study has a number of limitations, which are primarily related to the retrospective nature of the study design and the relatively small sample size, particularly of cases with available follow-up data. Larger series of FEL have, however, not been published to date. Furthermore, it is likely that not all cases of FEL which occurred in the referral population were reported to our center. Moreover, a bias towards reporting of more severe cases likely occurred. Data are also partially incomplete, which is the nature of retrospective studies using poison center data [22].

Conclusions

FEL is a distinct form of acute chemical toxic pneumonitis, which is caused by accidental aspiration of petroleum in most of the cases. It was mainly observed in young adults with a clear male predominance. The majority referred accidental aspiration and/or swallowing, whereas some patients could not remember any aspiration or swallowing. The mechanism of poisoning seems to have an impact on the clinical presentation, as pulmonary symp-

toms and fever were more prevalent after aspiration compared to swallowing. The combination of intense pleuritic chest pain, cough, dyspnea, and fever, or any of these symptoms after 'fire breathing' or erroneous swallowing of petroleum should alert the clinician to the diagnosis of FEL. The clinical findings of FEL resemble bacterial pneu-

monia, with pulmonary infiltrates, mainly in the lower field, and elevated inflammatory markers. An early antibiotic treatment in severe cases seems justified, considering that clinical, laboratory, and radiologic findings of FEL are overlapping with bacterial superinfection, which may lead to adverse outcomes.

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